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Case Docket No. 60,426-047

Date: September 7, 2000

Box Patent Application
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Sir:

Transmitted herewith for filing is a patent application of

Inventor(s): Ian R. McLean

For: TUNED HELMHOLTZ RESONATOR USING CAVITY FORCING

Enclosed are:

- ☒ 1 sheet of drawings - ☐ Formal ☒ Informal
☒ An Assignment of the invention to Siemens Canada Limited
☐ A certified copy of a application.
☒ A Combined Declaration and Power of Attorney
☐ An associate power of attorney.
☐ A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27.
☐ PTO Form 1449 with copies of patents cited in specification. (IDS).
☒ This application claims priority to Provisional Application No. 60/154,391 which was filed on September 16, 1999

The filing fee has been calculated as shown below:

	No. Filed	No. Extra	Small Entity		Large Entity	
Basic Fee			\$345		\$690	\$690
Total Claims	20-20		X 9	\$	X 18	\$
Indep. Claims	3-3		X 39	\$	X 78	\$
Multiple Dep. Claim(s) Present						\$
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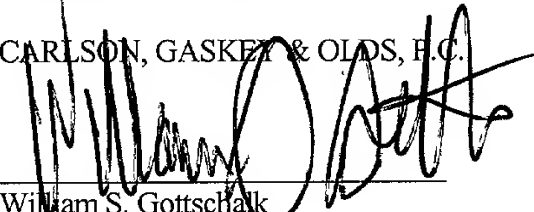
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☐ Any additional filing fees required under 37 CFR 1.16.

☒ Any patent application processing fees under 37 CFR 1.17.

Respectfully submitted,

CARLSON, GASKET & OLDS, P.C.


William S. Gottschalk
Registration No. 44,130
400 West Maple Road, Suite 350
Birmingham, MI 48009
(248) 988-8360

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TUNED HELMHOLTZ RESONATOR WITH CAVITY FORCING**BACKGROUND OF THE INVENTION**

This invention relates to a noise attenuation device for an air induction system, more particularly, the invention relates to a Helmholtz resonator for producing a forced response.

Internal combustion engines produce undesirable induction noise which adversely affects the output torque and volumetric efficiency of the engine. The induction noise produced by the engine depends on the particular engine configuration and is affected by such factors as the number of cylinders, the volume and shape of the intake manifold plenum and intake runners, and other induction system parameters. The induction noise is caused by a pressure wave that travels away from the combustion chamber toward the inlet of the air induction system. The induction noise may be reduced and the engine performance improved by producing a wave traveling in the direction of the combustion chamber 180° out of phase of the noise wave. To this end, noise attenuation devices have been developed.

A Helmholtz resonator is one widely used noise attenuation device. The Helmholtz resonator produces a pressure wave that counteracts primary engine order noise waves, which have the greatest negative impact on engine performance. Helmholtz resonators typically provide a passive response targeted at a particular band width of noise. Because the Helmholtz resonator typically provides a passive response, losses occur which decrease the overall effectiveness of the resonator by producing a pressure wave having a narrower bandwidth and smaller amplitude than desired. Variable Helmholtz resonators have been developed, which vary the volume of the resonator to vary the band width at which the resonator attenuates noise. However, these variable resonators do not address the passive losses associated with the Helmholtz resonator. Accordingly, it is desirable to widen the band width of a Helmholtz resonator to further attenuate noise and increase the performance of the engine.

SUMMARY OF THE INVENTION AND ADVANTAGES

The present invention provides a Helmholtz resonator including a chamber at least partially defining a cavity. The chamber has a neck which defines a passage that is in fluid communication with the cavity. The chamber and the neck produce a passive response to a sound wave produced by the internal combustion engine. The sound wave negatively effects engine performance. An active resonator is disposed within the chamber. The active resonator produces a forced response for supplementing the passive response and increasing the band width of the noise attenuating pressure wave.

The Helmholtz resonator is in fluid communication with a portion of an air induction system that defines a passageway that carries the sound wave. A driver is connected to the active resonator, which is preferably a loud speaker, to drive the loud speaker and produce the forced response. The driver preferably utilizes a signal source, such as an engine speed signal, to synchronize the forced response with the engine speed. A phase compensator synchronizes the forced response with the sound wave, and an amplifier amplifies the signal to drive the loud speaker.

Accordingly, the present invention increases the band width of the passive response of the Helmholtz resonator to more effectively attenuate noise and increase engine performance.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages of the present invention can be understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a schematic view of an internal combustion engine and induction system of the present invention;

Figure 2 is a perspective view of the Helmholtz resonator of the present invention; and

Figure 3 is a graphical view of pressure waves.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

An internal combustion engine 10 is shown in Figure 1. An air induction system 12 provides air to the engine 10 for mixture with fuel. The air/fuel mixture is burned in a combustion chamber. Air is provided from the atmosphere through an air intake 20 that feeds air through a filter box 18. The air travels along passageway 24 through a throttle body 16 which controls the amount of air that travels through the passageway 24 to the engine 10. The air is fed to an intake manifold 14 which then distributes the air to the combustion chambers through runners 15. During the combustion process noise pressure waves N are produced in the induction system 12 which reflect back into the combustion chambers and negatively effect engine performance.

A Helmholtz resonator 28 is shown in fluid connection with the passageway 24 to produce noise attenuating pressure waves which at least partially cancel the noise pressure waves N. Primary order engine noise, or the most undesirable engine noise, is related to the speed of the engine. Helmholtz resonators are designed to attenuate noise at the primary order. The frequency at which the primary order engine noise occurs is: $\text{number of cylinders}/2 \times \text{engine speed}/60$.

The Helmholtz resonator which is shown in Figure 2 includes a chamber 30 defining a cavity 32. A neck 34, which is shown as a tubular structure, extends from the chamber 30 and is in fluid communication with the cavity 32. The volume defined by the cavity 32 and the area of the neck 34 largely effect the band width of the noise attenuating frequency. The Helmholtz resonator 28 produces a passive response R_p that is approximately 180° out of phase from the noise wave N, shown in Figure 3. The passive response R_p has a bandwidth narrower and an amplitude smaller than desired.

The resonator 28 is shown arranged between the throttle body 16 and the intake manifold 14. However, it is to be understood that the resonator 28 may be arranged anywhere along the induction system 12. Preferably, the resonator 28 is arranged between the throttle body 16 and the intake manifold 14 because the largest portion of the noise pressure wave is reflected from the throttle body 16 back to the intake manifold 14. With the resonator 28 arranged as shown in Figure 1, a larger portion of the noise pressure wave may be attenuated by the resonator 28.

The present invention increases the band width of the resonator 28 by producing a forced response R_f shown in Figure 3. The forced response supplements the passive response R_p and together provide a wider band width and higher amplitude than the passive response from the Helmholtz resonator 28. As a result, a larger portion of the noise pressure wave may be attenuated. To this end, the present invention utilizes a active resonator, preferably a loud speaker 38, to produce the forced response. The chamber 30 includes a flange 36 to which the loud speaker 38 is attached. The flange 36 has an opening within which the loud speaker diaphragm 40 is disposed. The loud speaker 38 is driven by a driver 50 that drives the diaphragm 40 to produce a pressure wave that supplements the passive response pressure wave R_p . That is, the forced response R_f is in phase with the passive response R_p . The flange 36 includes pressure equalization ports 42 that equalizes the pressure on either side of the flange 36 to permit consistent operation of the resonator 28 of the present invention in various altitudes and changing atmospheric pressures. The equalization ports 42 are small enough to prevent pressure waves from exiting the cavity 32 through the equalization ports 42 so that the noise attenuating and pressure wave will not escape but will be directed to the noise wave. Preferably the pressure equalization ports 42 are about 1/8 inch in diameter.

Since the Helmholtz resonator 28 is designed to attenuate noise produced at the primary engine order, the driver 50 preferably includes a signal source 52 that senses the

speed of the engine. Such signals are commonly produced by proximeters that read notches on a timing gear. The speed signal is used by an ECU 58 for devices such as the tachometer and engine control. The signal source 52 is sent to a phase compensator 54 that adjusts the sinusoidal output from the signal source 52 so that it is approximately 180° out of phase with the noise pressure wave. The phase compensator 54 adjusts for such parameters as the speaker response, the volume response of the Helmholtz resonator, and the neck response of the Helmholtz resonator. These parameters may be determined through experimentation during the engine development process. An audio amplifier 56 amplifies the signal from the phase compensator 54 which is typically a low voltage signal. The signal from the audio amplifier 56 drives the loud speaker 38 to produce the forced response. The forced response R_f and passive response R_p , which are of wider band width and greater amplitude, are radiated back to the engine 10 to increase the engine performance.

While a branch Helmholtz resonator is shown it is to be understood that the present invention may also be used with an inline Helmholtz resonator. The invention has been described in an illustrative manner, and it is to be understood that the terminology that has been used is intended to be in the nature of words of description rather than of limitation. Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

CLAIMS

What is claimed is:

1. A Helmholtz resonator comprising:
a chamber at least partially defining a cavity;
5 a neck in said chamber and having a passage in fluid communication with said cavity,
said chamber and neck producing a passive response to a sound wave; and
an active resonator disposed within said chamber, said active resonator producing a
forced response for supplementing said passive response.

10 2. The Helmholtz resonator according to claim 1, wherein said neck is a tubular
structure extending from said chamber.

3. The Helmholtz resonator according to claim 1, wherein said active resonator is
a loudspeaker.

15 4. The Helmholtz resonator according to claim 3, wherein said loudspeaker is a
woofer.

5. The Helmholtz resonator according to claim 3, wherein said chamber includes
20 a flange with said loudspeaker supported thereon, and said loudspeaker having a diaphragm
disposed within an opening in said flange for producing said forced response.

6. The Helmholtz resonator according to claim 5, wherein said flange includes at
least one pressure equalization port there through in fluid communication with said cavity.

7. The Helmholtz resonator according to claim 6, wherein said flange is arranged opposite said neck.

8. An induction noise attenuation system for a combustion engine comprising:
5 a portion of an air induction system defining a passageway carrying a sound wave;
a Helmholtz resonator having a chamber at least partially defining a cavity and a neck
in said chamber fluidly connecting said portion of said air induction system and said cavity,
said chamber and said neck producing a passive response to said sound wave;
an active resonator disposed within said chamber; and
10 a driver connected to said active resonator producing a signal for driving said active
resonator and producing a forced response for supplementing said passive response.

9. The system according to claim 8, wherein said driver includes a signal source
that detects a speed of the combustion engine for synchronizing said forced response relative
15 to said speed.

10. The system according to claim 9, wherein said signal source is engine RPM.

11. The system according to claim 9, wherein said driver includes a phase
20 compensator for synchronizing said forced response approximately 180° out of phase with
said sound wave.

12. The system according to claim 9, wherein said driver includes an amplifier for
amplifying a signal from said signal source.

13. The system according to claim 8, wherein said passageway is arranged
between an intake manifold and a throttle body.

14. The system according to claim 8, wherein said active resonator is a
5 loudspeaker.

15. A method of attenuating noise in an induction system comprising:

- 10
- a) sensing an engine speed;
 - b) producing a phase compensated engine speed signal;
 - c) driving a loudspeaker with the phase compensated engine speed signal; and
 - d) propagating a sound wave with the loudspeaker to attenuate the noise in the
induction system.

16. The method according to claim 15, further including the step of:

- 15
- e) amplifying the engine speed signal.

17. The method according to claim 15, further including the step of:

- 20
- f) propagating a passive sound wave with a Helmholtz resonator, wherein step d)
supplements the passive sound wave.

18. The method according to claim 17, wherein step b) includes determining a
loudspeaker response.

19. The method according to claim 17, wherein step b) includes determining a
25 Helmholtz resonator cavity response.

20. The method according to claim 17, wherein step b) includes determining a Helmholtz resonator neck response.

TUNED HELMHOLTZ RESONATOR WITH CAVITY FORCING

ABSTRACT OF THE DISCLOSURE

A Helmholtz resonator includes a chamber at least partially defining a cavity. The
5 chamber has a neck which defines a passage that is in fluid communication with the cavity.
The chamber and the neck produce a passive response to a sound wave produced by the
internal combustion engine. The sound wave negatively effects engine performance. An
active resonator is disposed within the chamber. The active resonator produces a forced
response for supplementing the passive response and increasing the band width of the noise
10 attenuating pressure wave. The Helmholtz resonator is in fluid communication with a portion
of an air induction system that defines a passageway that carries the sound wave. A driver is
connected to the active resonator, which is preferably a loud speaker, to drive the loud
speaker and produce the forced response. The driver preferably utilizes a signal source, such
as an engine speed signal, to synchronize the forced response with the engine speed. A phase
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amplifies the signal to drive the loud speaker.

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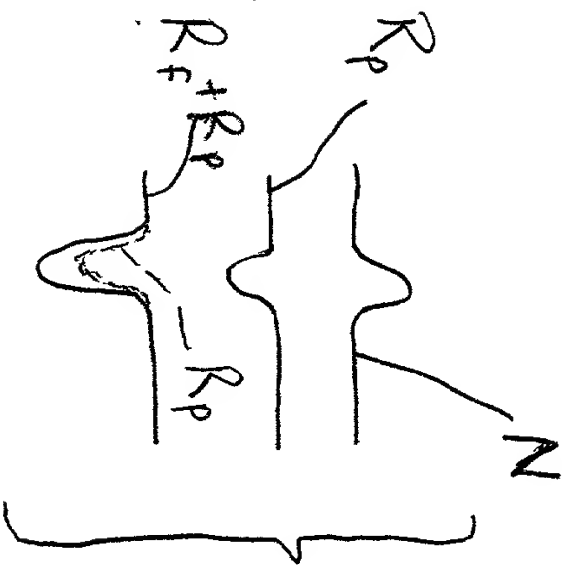


Fig. 3

Fig. 3 is a cross-sectional view of the device showing the core and the layers.

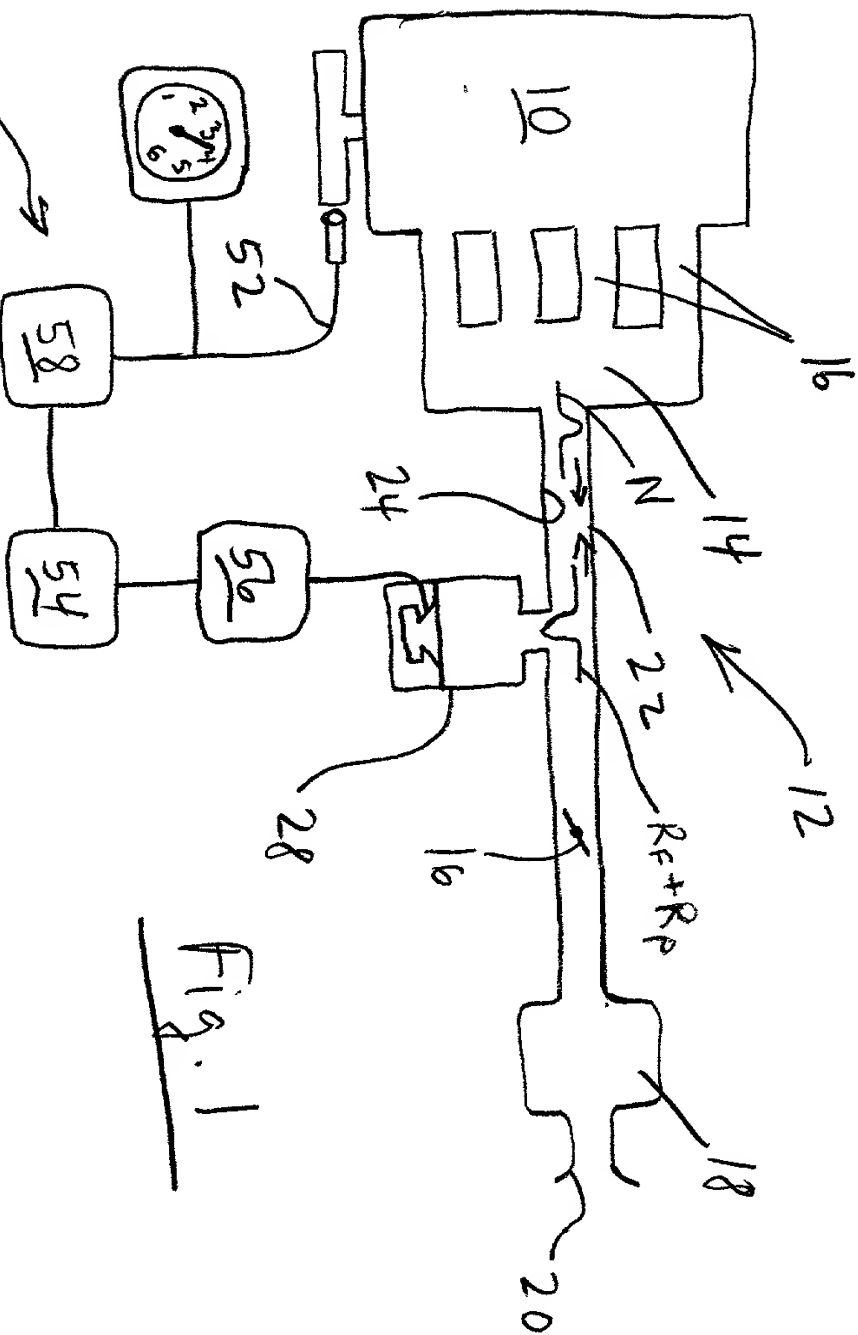


Fig. 1

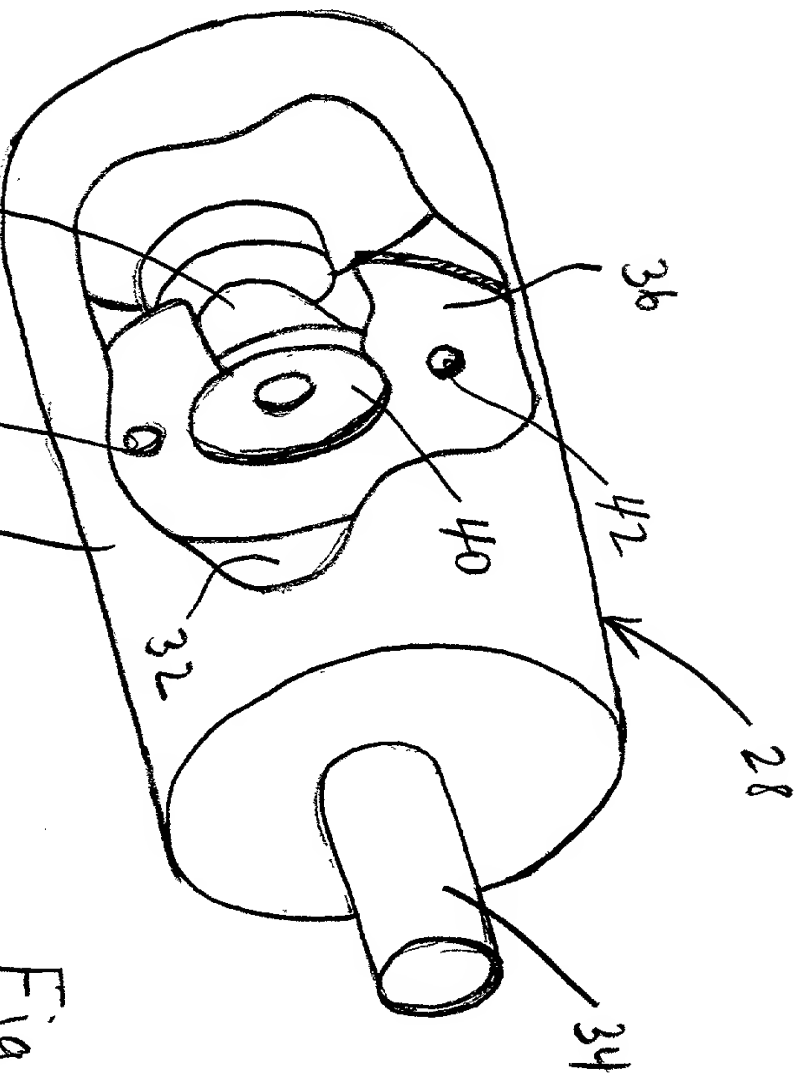


Fig. 2

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I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT International application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (If applicable)

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Adel A. Ahmed	29,606	Robert T. Canavan	37,592
I. Marc Asperas	37,274	Joseph S. Godispoti	31,819

☒ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☐ Customer Number or Bar Code Label ☒ Correspondence address below

Name	Elsa Keller				
Address	SIEMENS CORPORATION				
Address	186 Wood Avenue South				
City	Iselin	State	NJ	ZIP	08830
Country	US	Telephone	732 321 3024	Fax	732 321 3014

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Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle (if any))	Family Name or Surname
Ian R.	McLean

Inventor's Signature	Date		
<i>Ian R. McLean</i>	7/9/00		
Residence: City	State	Country	Citizenship
Chatham	Ontario	Canada	Canada

Post Office Address: 140 Park Avenue, Apt. 104

Post Office Address	City	State	ZIP	Country
	Chatham	Ontario	N7M 3V6	Canada

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Attorney Docket Number 99P7811/60,426-047

First Named Inventor Ian R. McLean

COMPLETE IF KNOWN

Application Number /

Filing Date Herewith

Group Art Unit

Examiner Name

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TUNED HELMHOLTZ RESONATOR USING CAVITY FORCING

the specification of which (Title of the Invention)

☒ Is attached hereto
OR

☐ was filed on (MM/DD/YYYY) as United States Application Number or PCT International

Application Number and was amended on (MM/DD/YYYY) (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?	
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I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

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60/154,391	September 16, 1999	

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REGISTERED PRACTITIONER INFORMATION (Supplemental Sheet)

Name	Registration Number	Name	Registration Number
Lawrence C. Edelman	29,299	Pasquale Musacchio	36,876
Mark H. Jay	27,507	Eric C. Swanson	40,194
Rosa S. Kim	39,728	Tracy L. Hurt	34,188
Peter A. Luccarelli, Jr.	29,750	John Musone	44,961
Jeffrey P. Morris	25,307		
Donald B. Paschburg	33,753		
Darryl A. Smith	37,756		
Daniel J. Staudt	34,733		
Heather S. Vance	39,033		
Scott T. Weingaertner	37,756		
Robert A. Whitman	36,966		
Ira Lee Zebrak	31,147		
John E. Carlson	37,794		
David J. Gaskey	37,139		
William S. Gottschalk	44,130		
Kerrie A. Laba	42,777		
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